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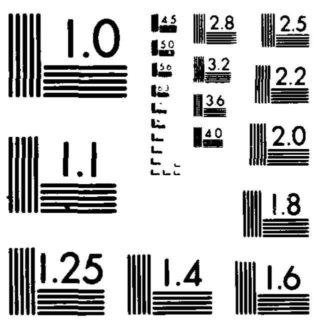
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REPORT SD-TR-81-74

LEVEL II

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The Global Pc 5 Event of November 14-15, 1979

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This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

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Large amplitude Pc-5 waves with 7-8 minute quasi-periodic variations were observed almost continuously for the forty-eight hours of November 14-15, 1979 by several spacecraft in or near geostationary orbit on the day-side portions of their orbits. The waves were observed as large modulations in both the electron and ion fluxes over a wide range of energies (~1 to 500 keV) by the spacecraft 1976-059, 1977-007, 1979-053, P78-2, and GEOS-2 and as magnetic field peak-to-peak modulations of 15-25 γ by the P78-2 and GOES-2 and -3

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magnetometers. The remarkably long persistence of these waves contrasts substantially with observations of typical flux modulation events which usually last less than one hour and which typically show little modulation of the ≥150 keV proton fluxes. Data taken concurrently by the ISEE spacecraft in the solar wind and outer magnetosphere indicate that the solar wind also had unusual properties. ISEE-3 measurements indicate that the solar wind velocity (~350 km/sec) and density (~2 cm^{-3}) were simultaneously very low for this period. The alpha-to-proton ratio for the solar wind plasma attained an extremely low value (< 1%) early in the event. These solar wind properties imply a much reduced dynamic pressure on the magnetosphere during this period. Consequently, the ISEE-1 and -2 spacecraft passed through the magnetopause at the uncommonly large radial distance of 18 R_E at ~0830 local time where the typical magnetopause geocentric distance is 12 R_E. The exceptional solar wind and outer magnetospheric conditions may have determined the unusual properties of the ULF event observed near geostationary orbit. Some candidate mechanisms for producing these oscillations are presented, but no definitive explanation for this event can be given at present.

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PREFACE

One of the authors (PRH) would like to thank E. W. Hones, Jr., and J. T. Gosling for discussions of the ISEE plasma data used in this paper. This work was completed while one of the authors (CWA) was a research associate at the cooperative Institute for Research in Environmental Sciences at the University of Colorado and NOAA.

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CONTENTS

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TABLES

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Introduction

Geomagnetic pulsations observed at the earth's surface have had a long history of study. Jacobs [1970] reviewed the general subject of pulsations with the major emphasis on ground-based observations for the various classes (Pc and Pi) of events but he included a description of early observations (*ca* 1960) of Pc pulsations in space. The Pc 5 class of pulsations were defined to be those showing a regular character with a period in the range of 150-600 seconds. The occurrence distribution in local time showed maxima near 0600 and 1800 MLT for the auroral zone, but other reports indicated only a morning maxima (in 1958) and either a midday maximum or diurnal maximum (middle latitudes). Typical events are limited in longitude - 115° being exceptional.

Nishida [1978] presents a good summary of the modern theories of the mechanisms for exciting Pc oscillations. In particular, he points out that resonances in the inner magnetosphere can be excited by a monochromatic wave (produced for example by a Kelvin-Helmholtz instability at the magnetopause) exciting a field line resonance or by a broad band noise source exciting a surface wave at a sharp density gradient (such as the plasmapause).

A review of ULF oscillations as observed in the magnetosphere was done by McPherron et al. [1972]. The data that they reviewed were obtained by magnetometer experiments on a variety of spacecraft. Pc 5 oscillations were found to have an occurrence maximum on the dayside of the magnetosphere and were observed most frequently for $L > 8$. They also stated that it was not clear that the classification scheme used for ground-based observations was also appropriate for satellite observations.

In recent work [Higbie et al. 1978; Baker et al. 1980] we found that the local time distribution of flux pulsation events, observed with geostationary

satellites, depended on both the magnetic latitude and the season. Specifically, lower-latitude observations showed a midday maximum as did the Fall-Winter observations at higher latitude. Spring-Summer observations at high geomagnetic latitudes show maxima at morning and dusk. Most events had periods of five minutes or less and lasted less than approximately one hour.

Lin et al. [1976] reported quasi-periodic variations in the electron flux and in the magnetic field with periods ranging from 2 to 12 minutes from observations at geostationary orbit. They ascribed the observed variations in the electron fluxes to adiabatic effects resulting from the compression of the magnetic field by hydromagnetic waves. They also derived a theoretical relationship between the variations in flux and the variations in the local magnetic field and showed it agreed with their observations for the limited range of pitch angles available to their instrument.

The cold ion flux data and magnetometer data from the Ogo 5 satellite were used by Singer and Kivelson [1979] in a survey of Pc 5 waves. They concluded that the mode of oscillation for seven of the eleven examples of Pc 5 waves found in their survey was probably the fundamental odd mode (a node in the magnetic field perturbation at the equator). It should be noted that observational methods which depend on variations in particle fluxes are most sensitive to magnetic perturbations at the equator, so the probability of observing flux variations at the magnetic equator is reduced for all odd mode waves. Lanzerotti et al. [1976] also concluded that ULF waves observed by both Explorer 5 and an array of ground-based magnetometer stations had the characteristics of an odd mode. They noted, in addition, that a satellite at the equator might see a compressional component arising from the excitation source, even if the shear components of the magnetic field variations were small. Kokubun et al. [1976] also studied Pc 5 waves observed by spacecraft

and ground based instruments. In one event they found that the largest variations, observed by Ogo 5 at a low geomagnetic latitude, were in the azimuthal component of the magnetic field. On the ground, the largest varations were in the H component and the polarization was in the opposite sense for the two conjugate stations. They concluded that the wave was an odd mode but there was a rotation of the major axis of the polarization between the spacecraft location and the ground due to ionospheric effects. Kokubun et al. found that Pc 5 waves were mostly observed at magnetic latitudes of 10 to ~30°, L values of 6-13 R_E, and in the morning sector between 0300 and 1100 LT. A much smaller occurrence probability was found for observing Pc 5 waves past noon.

In the Pc 4 frequency band, Rostoker et al. [1979] observed highly monochromatic amplitude-modulated oscillations of the earth's magnetic field in the auroral zone. These pulsations are quite rare, but may reoccur on successive days during quiet geomagnetic conditions. A similar long duration Pc 4 event was also observed by spacecraft in geostationary orbit [Arthur, 1979]. Su et al. [1979] observed a Pc 4 event which exhibited large amplitude waves in the proton channels of the NOAA instrument on ATS 6.

Instrumentation

Data from ten spacecraft were examined for evidence of pulsations. These ten spacecraft and their associated instruments are listed in Table I. The relative locations of the spacecraft in geostationary orbit are shown in Figure 1 at the time when P78-2 was at apogee. The trace of the orbit for ISEE-1 and -2 is also illustrated for the outbound pass between 1530 UT on November 14 and 0330 UT on November 15.

The three geostationary spacecraft 1976-059, 1977-007, and 1979-053 have energetic particle sensors onboard which are sensitive to electrons (plus

Table I

List of Spacecraft and Instruments Used in Study

Spacecraft	Location	Instrument	PI and Institution
1976-059	Geostationary	Charged Particle Analyzer	Higbie, LASL
1977-007	Geostationary	Charged Particle Analyzer	Higbie, LASL
1979-053	Geostationary	Charged Particle Analyzer	Higbie, LASL
GOES-2	Geostationary	Magnetic Field Monitor	Williams, NOAA
GOES-3	Geostationary	Magnetic Field Monitor	Williams, NOAA
GEOS-2	Geostationary	Electron and Proton Pitch Angle Distribution Experiment	Wilken and Korth, MPAE
P78-2	Near-geostationary	Electrostatic Plasma Analyzers and Energetic Proton Detector	Fennell, Aerospace
ISEE-1	Outer magnetosphere	Flux Gate Magnetometer	Russell, UCLA
ISEE-2	Outer magnetosphere	Fast Plasma	Paschmann, MPI/LASL
ISEE-3	Libration Point	Solar Wind Plasma	Bame, LASL/MPI

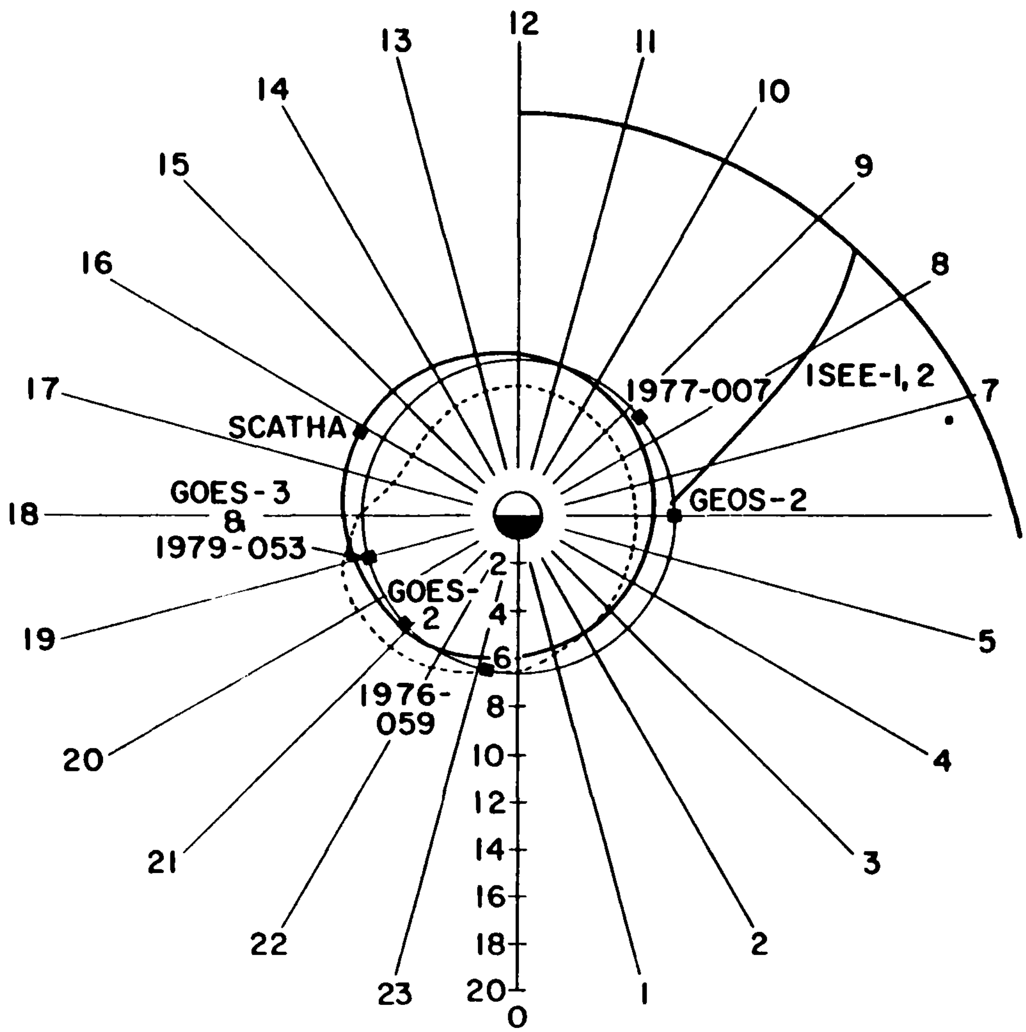

Fig. 1. Relative locations of geostationary spacecraft at the time when the P78-2 spacecraft was near apogee at 0400 UT. The projection of the outbound ISEE-1 and -2 spacecraft orbit is shown between 1530 UT on November 14 and 0330 UT on November 15, 1979. Plasmapause and magnetopause boundaries are scaled to the observations of the magnetopause crossing by ISEE-1 and -2.

ions) in the 30 keV to 2 MeV energy range and to ions in the ~150 keV to 150 MeV energy range. These Charged Particle Analyzers (CPA) have been described elsewhere in greater detail [Higbie et al., 1978; Baker et al., 1979]. Data from the instruments on 1976-059 and 1977-007 were used in earlier studies of pulsation events [Higbie et al., 1978; Baker et al., 1980].

Plasma data from 0.2 to 19.4 keV and energetic proton data from 19-3300 keV were available from the Aerospace electrostatic analyzer (experiment SC2) and magnetic field data from the GSFC magnetometer (experiment SC 11) on board the P78-2 spacecraft were available for this event. These instruments are described in detail in Stevens and Vampola [1978].

The LASL/MPI instruments on ISEE-1 and -2 measure ions with energy/charge (E/Q) with two selectable energy sweeps, which together cover the range 50 eV to 39 keV. On ISEE-3 the ion E/Q range extends from 240 eV to 11 keV. These instruments were described in more detail in Bame et al. [1978a,b].

The magnetometers on ISEE-1 and -2 were described by Russell [1978] and that on ISEE-3 by Frandsen et al. [1978]. The instruments on GEOS-2 (Experiment S-321 for energetic particles and S-331 for magnetic fields) are described in Knott [1975].

Observations Near Geostationary Orbit

The reason our interest was attracted to this event is that it exhibits an exceptional persistence for Pc 5 waves in the magnetosphere. The oscillations were seen as large amplitude variations in the energetic particle flux, plasma density, and magnetic field data. Periods were typically 8 minutes and the oscillations lasted for hours at a time. Unusually large modulations were observed nearly continuously on November 14 and 15, 1979 in the dayside data taken near the geostationary orbit by the spacecraft included in this study.

Our observations fall into two classes: particle flux modulations and magnetic field modulations. The fact that flux modulations as observed by the CPA sensors are associated with Pc 5 waves is due to the conservation of the first two adiabatic invariants while the local magnetic field is alternately compressed and relaxed by the hydromagnetic wave. The spacecraft is positioned on different field lines ($L \sim B^{-1/3}$) as the field changes, but the particle energy may also change since the first adiabatic invariant is conserved ($\mu \sim E_{\perp}/B$). Since the flux has a radial gradient in L and typically is a falling function of E, the magnetic field variations can produce variations in the particle flux. Lin et al. [1976] give a detailed treatment of these effects.

Figures 2 and 3 present exemplary periods when pulsations were seen at geostationary orbit. There are several noteworthy points to be made. Previous studies [Higbie et al., 1978; Baker et al., 1980] have indicated that oscillations are most usually found in the low energy electrons fluxes. Here, the oscillations appear to be most prominent for the low energy protons. The modulations observed in this event are unusually large for proton oscillations. Since the oscillations appear to be in-phase for both electrons and protons at all energies, it is probable in this case that oscillations of field lines (and the consequent motion of the particles having a radial gradient) are the most likely explanation of these results.

To determine if pulsations were present at universal times and local time locations other than those available for CPA data, magnetic field, plasma and energetic proton data from P78-2 were examined for pulsations. Figure 4 shows plasma oscillations as envelopes forming upper and lower bounds to the high frequency spacecraft spin modulations of the electron fluxes. The total field magnitude from the GSFC magnetometer on P78-2 shows very clear and pronounced

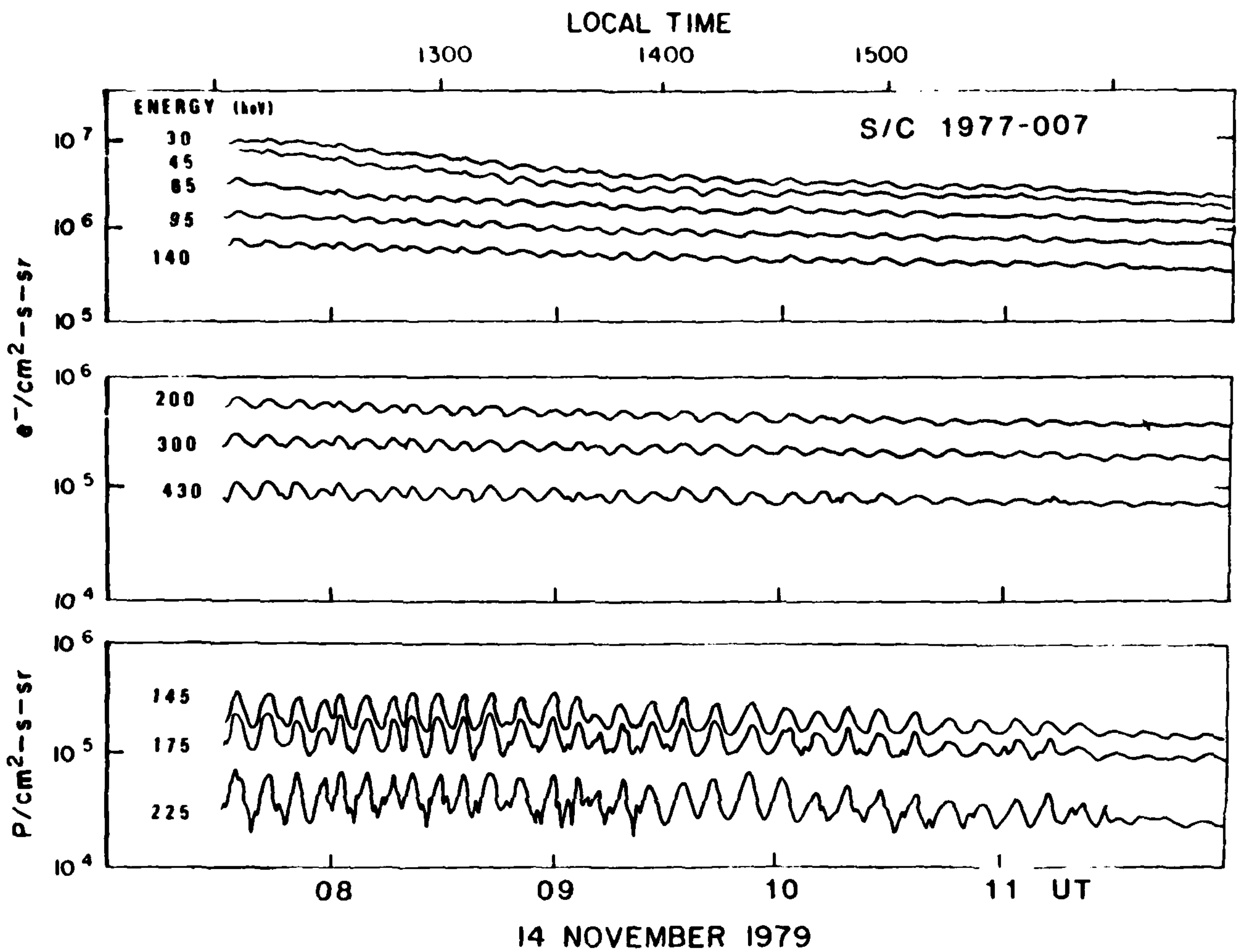

Fig. 2. *A portion of the record for spacecraft* 1977-007 for November 14. The spin averaged counting rate is plotted vs *time. The basic time* resolution is one spacecraft rotation, approximately ten seconds. Energy thresholds in keV are indicated beside each curve.

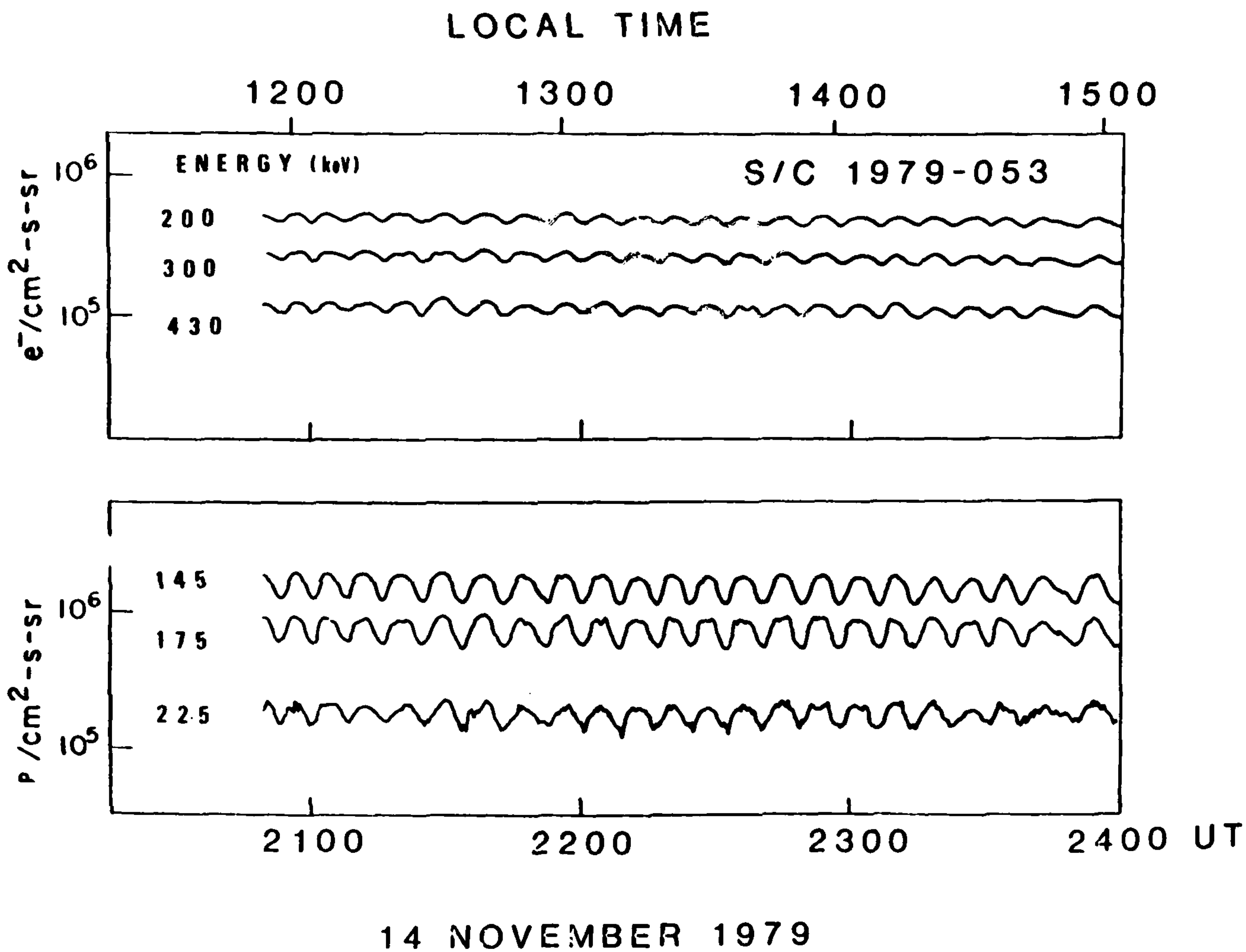

Fig. 3. A portion of the record for spacecraft 1979-053. The same comments apply as in Figure 4.

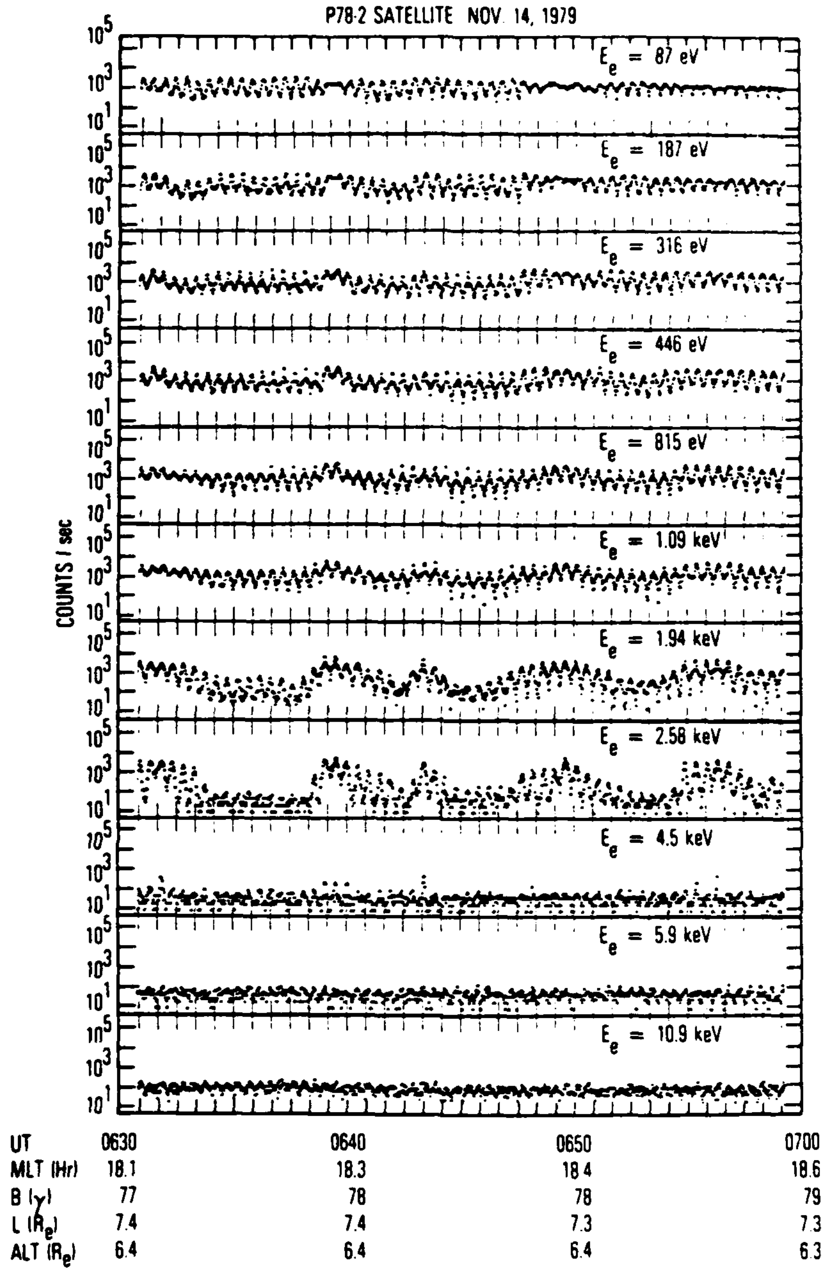

Fig. 4. Counting rate plot for plasma electrons. The Pc 5 modulations are seen as an envelope modulating the shorter period variations due to the spacecraft spin.

variations. P78-2 moved outward in nominal L value from 5.54 to 7.57 R_E during the period shown in Fig. 5a. These data were used to measure the periods discussed below. The low energy electron data (187 eV to 19.4 keV) showed oscillations in the lower energy channels, but not in the higher energy channels. It may be that the spatial gradient responsible for the oscillations observed at higher energies is very small at energies between the very energetic particles and the plasma particles. On the other hand, the plasma oscillations may be due to a bulk velocity modulation in response to the electric field component of the hydromagnetic wave [Singer and Kivelson, 1979 and references therein] whereas the more energetic particles respond mostly to the magnetic field variations.

Magnetometer measurements were also obtained from GOES-2 and -3. The oscillations, observed by GOES-3 on November 14, were largest for the component nearest to the nominal dipole field direction, next largest for the radial component and least in the remaining orthogonal component. These data are again consistent with the models of Pc-5 waves cited in the Introduction.

As a start in the systematic study of this phenomenon, we plotted the data as a function of local time as shown in Figures 5a and 5b. The figures show the data availability as a light bar at the top of the panel corresponding to a given spacecraft. The heavy bar indicates those intervals when oscillations were observed in the data. Tic marks at the top of each panel indicate the UT time of observation. The intervals between successive minima or "quasiperiods" are plotted when they could be clearly determined. From these graphs it is at once clear that the oscillations are mainly confined to the dayside. There is some ambiguity introduced in the data since the spacecraft are located at discrete points (the regions of oscillation might be patchy) and the time coverage is not complete. Nonetheless, we take confinement of

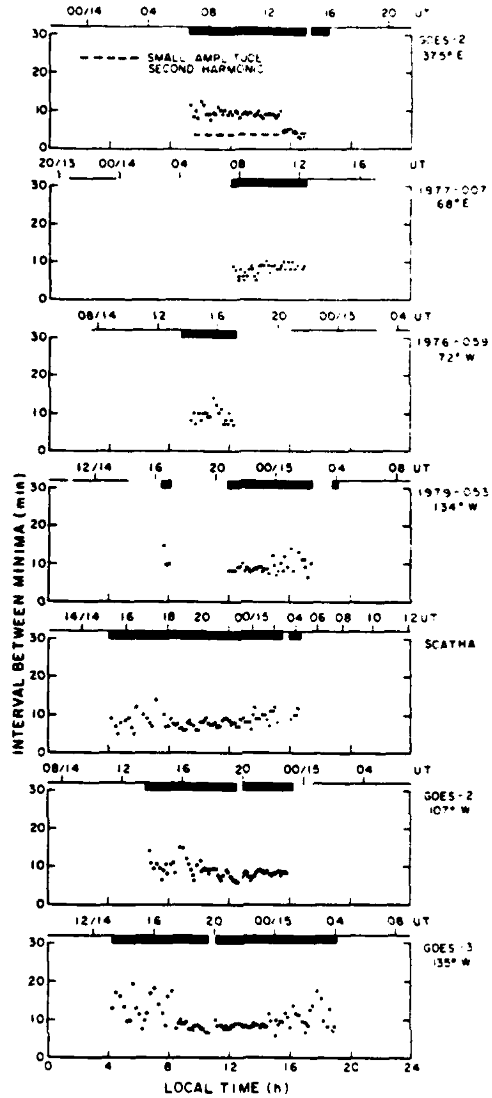

Fig. 5a. Summary of pulsation data observed near geostationary orbit. Each panel is labeled with the spacecraft name to the right, the intervals data were available are shown by a thin bar at the top of the panel, the intervals oscillations were observed are indicated by a thick bar and the UT time scale is marked also. The quasi periods are also shown when they could be determined.

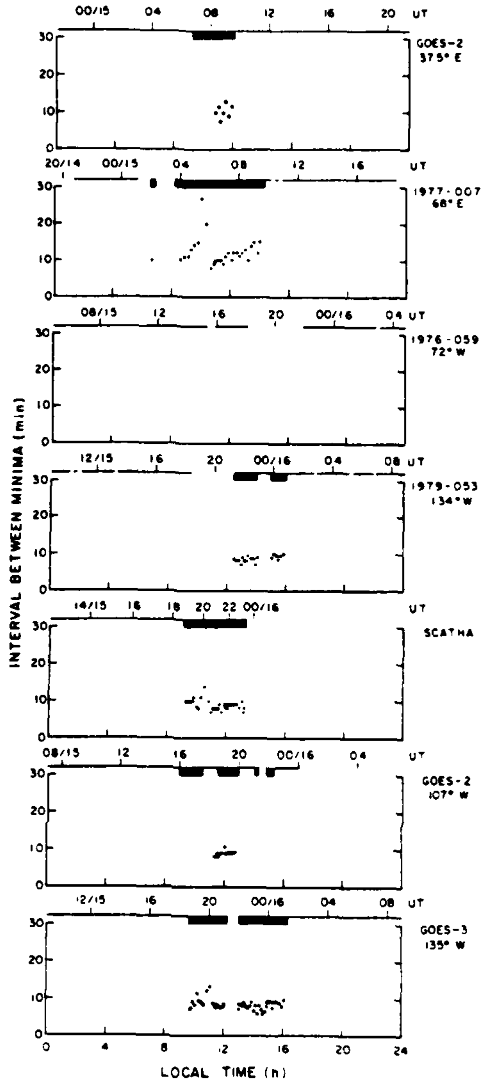

Fig. 5b. Summary of pulsation data observed near geostationary orbit. Each panel is labeled with the spacecraft name to the right, the intervals data were available are shown by a thin bar at the top of the panel, the intervals oscillations were observed are indicated by a thick bar and the UT time scale is marked also. The quasi periods are also shown when they could be determined.

oscillations to the dayside as a working hypothesis. Another characteristic which can be seen from these plots is the tendency for the quasiperiods to be longer and perhaps more erratic near dawn and dusk.

Geomagnetic Observations

The days of November 14 and 15, 1979 were quiet. The three hour Kp indices were 5, 4^+, 3^-, 1, 1^-, 1, 0^+, 0 for November 14 and 0, 1, 1^-, 1^+, 1^+, 1^-, 0^+, 1 for November 15. The latter day was marked as the Q5 day for the month, whereas November 13 was the most disturbed day (D1) for the month. The ΣK_p values for the 13th, 14th, and 15th were 35^+, 15, and 6^+.

Figure 6 illustrates the magnetometer record for several auroral zone stations for the two days under investigation. Except for the early UT hours of November 14 the traces are virtually straight lines. The magnetograms show evidence for very low levels of pulsation activity. Tromso, Thule, and Narssarssuaq show signs of a SC at approximately 0330 UT on November 15 that did have observable effects on the pulsations as discussed below.

ISEE-1 and -2 Observations

The relative positions of the spacecraft during this event were illustrated in Figure 1. In that figure the magnetopause is scaled to 18 R_E which corresponds to the position where the ISEE-1 and -2 spacecraft cross that boundary. The two spacecraft first encounter the boundary layer plasma on the outbound leg of their orbit at $\sim$0110 UT on November 15 at a distance of 17 R_E. The plasmapause is scaled according to Carpenter's 1966 profile given in Maynard and Grebowsky [1977]. The seven spacecraft are shown at 0400 UT when the P78-2 spacecraft was near apogee. The P78-2, ISEE-1 and -2, and geostationary orbits are shown also.

Figure 7, taken from Fairfield [1971], demonstrates how extremely atypical this observation of the magnetopause location is. The x in the upper left

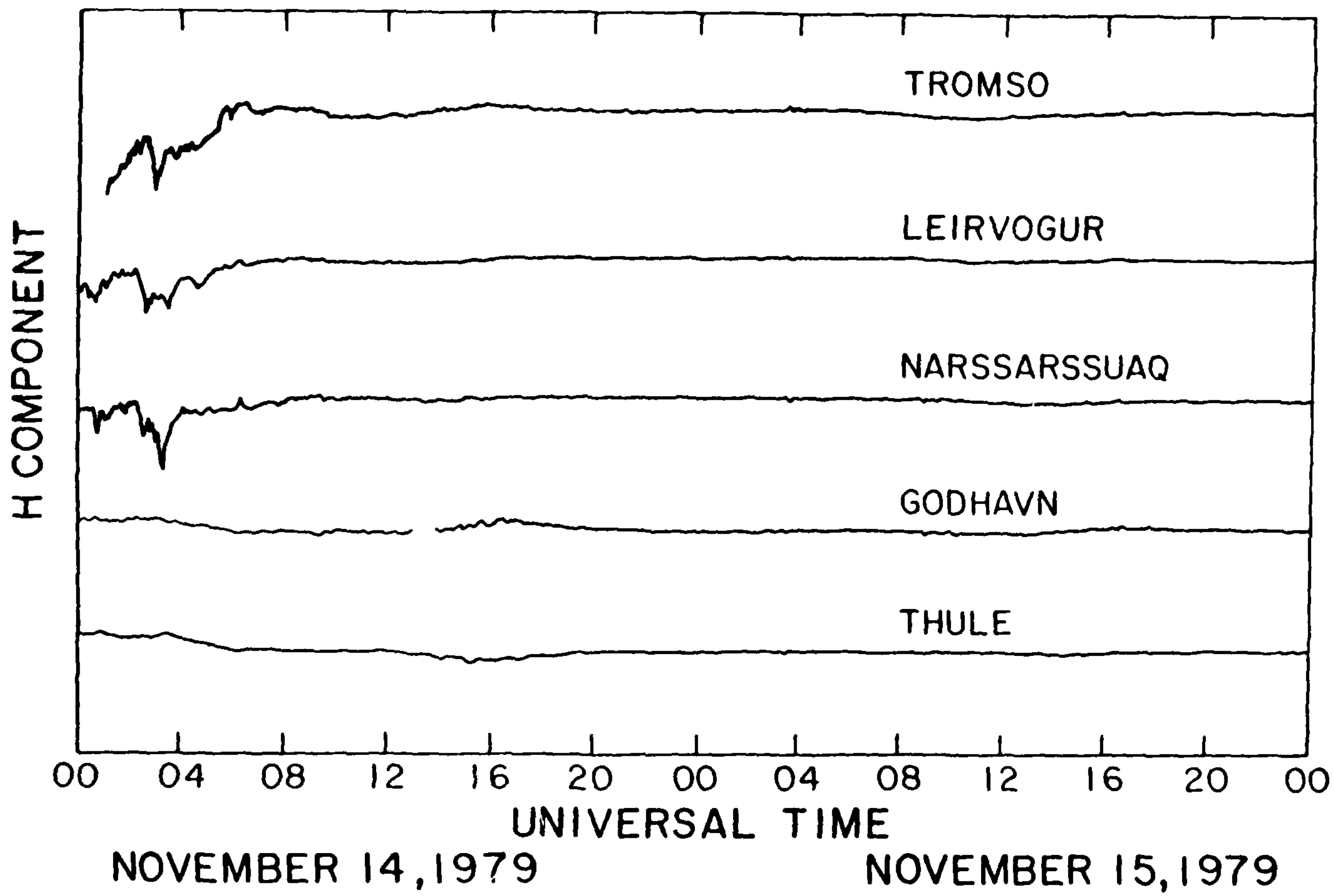

Fig. 6. H component magnetometer traces for several auroral zone stations.

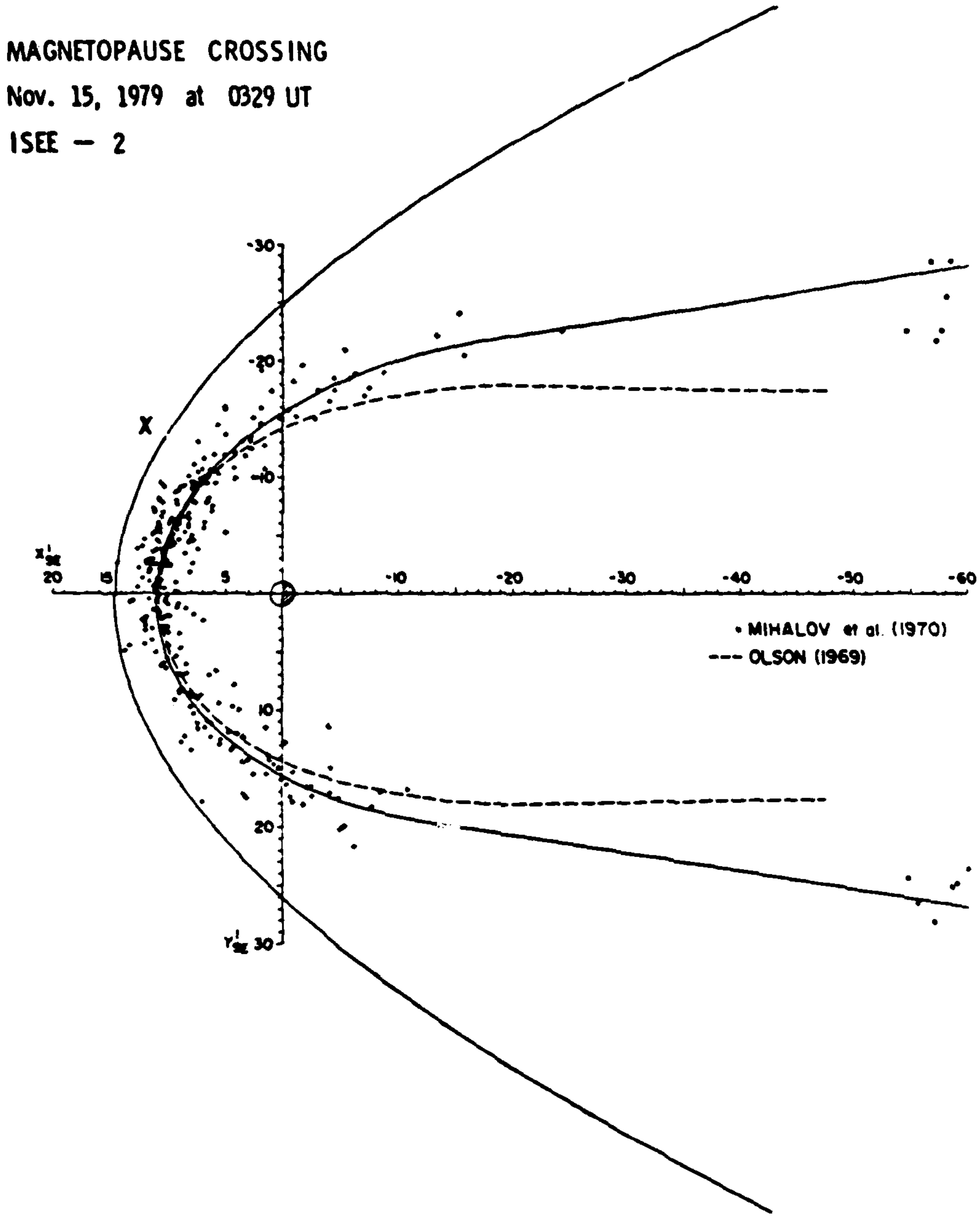

Fig. 7. The position of the magnetopause as observed by Isee 1 and 2 is illustrated by an X on the figure given by Fairfield [1971] for the nominal magnetopause position.

quadrant is the location of the ISEE-1 and -2 magnetopause crossing which should be compared with the distribution of crossings obtained from IMP 1-4 and Explorer 33 and 35 data.

There is also evidence for oscillations at the magnetopause boundary. The ISEE-2 plasma density plotted in Figure 8 demonstrates this feature. Pulsations with periods of roughly 5.5 minutes can be seen although large phase changes also occur. The large density increase at 0325 UT marks the entry into the magnetosheath and solar wind.

Solar Wind Observations

The solar wind conditions during the course of this event were continuously monitored by the ISEE-3 spacecraft, which was orbiting the libration point 200 R_E upstream from the earth. Figure 9 (E. J. Smith, private communication, 1980) shows that the IMF was strongly southward for the day preceding the period discussed in this paper. The B_y component reversed sign and the B_z component became less negative early on the fourteenth. By the fifteenth of November, B_z was northward for a good fraction of the time.

The most unusual aspect of the solar wind parameters was the concurrently low values of the proton density and velocity. These are normally statistically anticorrelated as shown in Figure 10a. The observed density was ~ 2 cm^{-3} and the velocity was ~ 350 km/sec on November 14. The probability of observing such a combination is much less than 5%. During the same time period the alpha-to-proton ratio, as measured by the solar wind instrument on ISEE-3, was abnormally low (< 1%). This observation (dashed line) is compared with a statistical sample of such measurements in Figure 10b. These factors imply that the dynamic pressure on the magnetosphere was very low.

There was a density enhancement observed at ISEE-3 approximately 60 minutes prior to the SC observed at 0330 UT on November 15 (cf. Geomagnetic

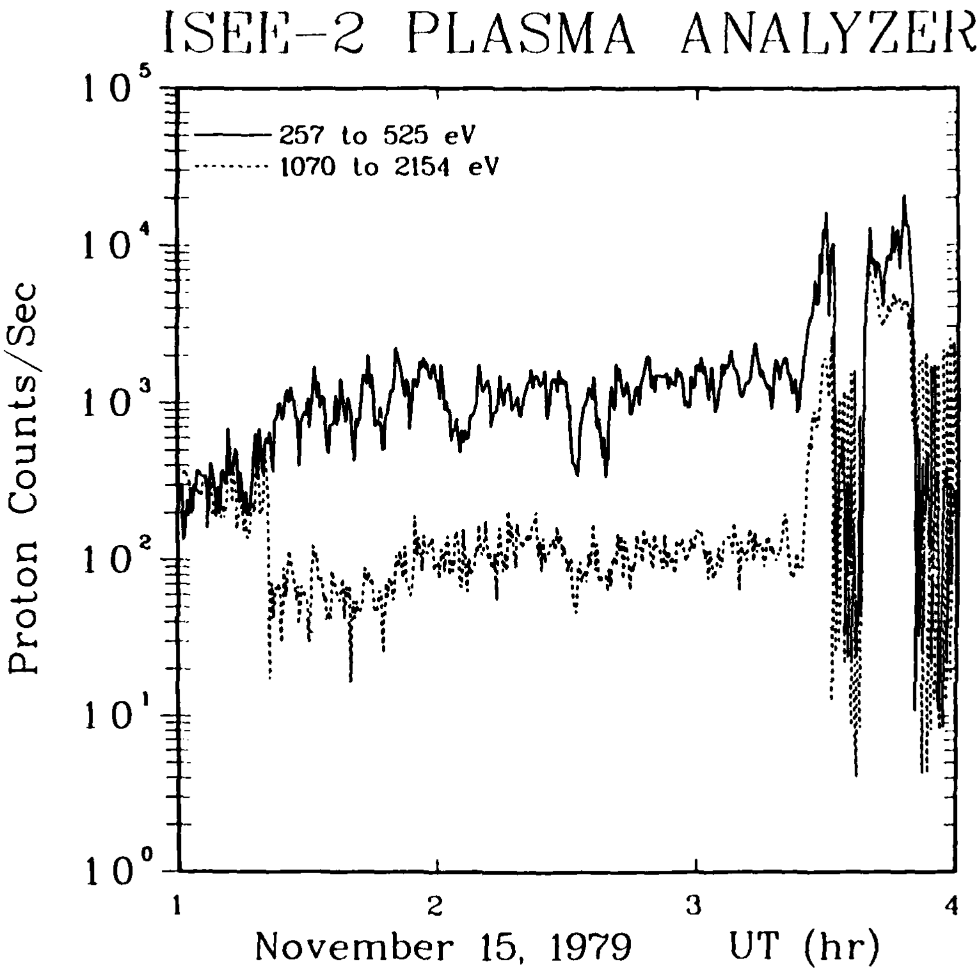

Fig. 8. ISEE-2 density plot during magnetopause crossing. Quasi-periodic oscillations with periods of ~5.5 minutes can be observed.

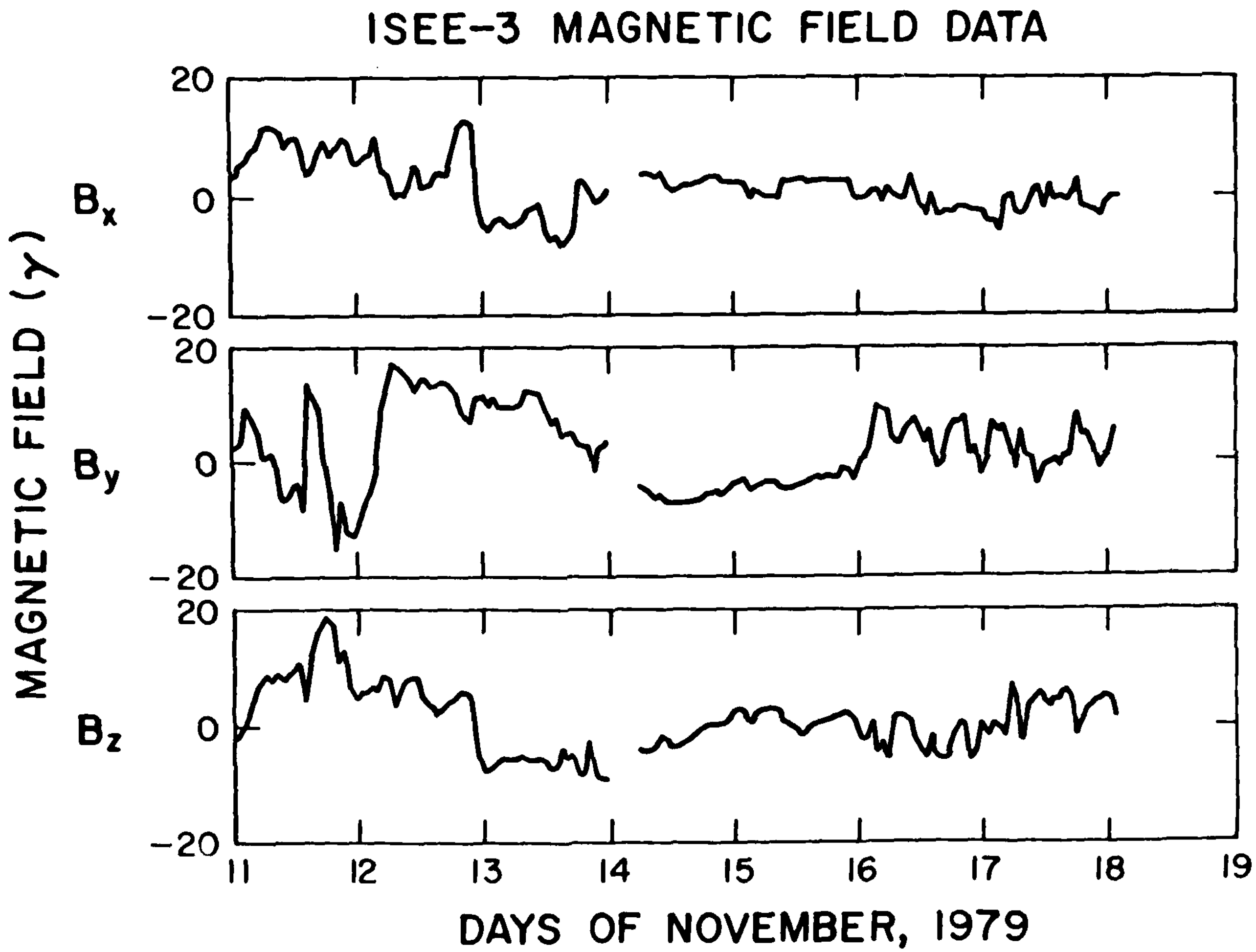

Fig. 9. Interplanetary magnetic field measured at ISEE-3 for the several days preceding and following the days, November 14 and 15, when strong Pc 5 waves were observed near the geostationary orbit.

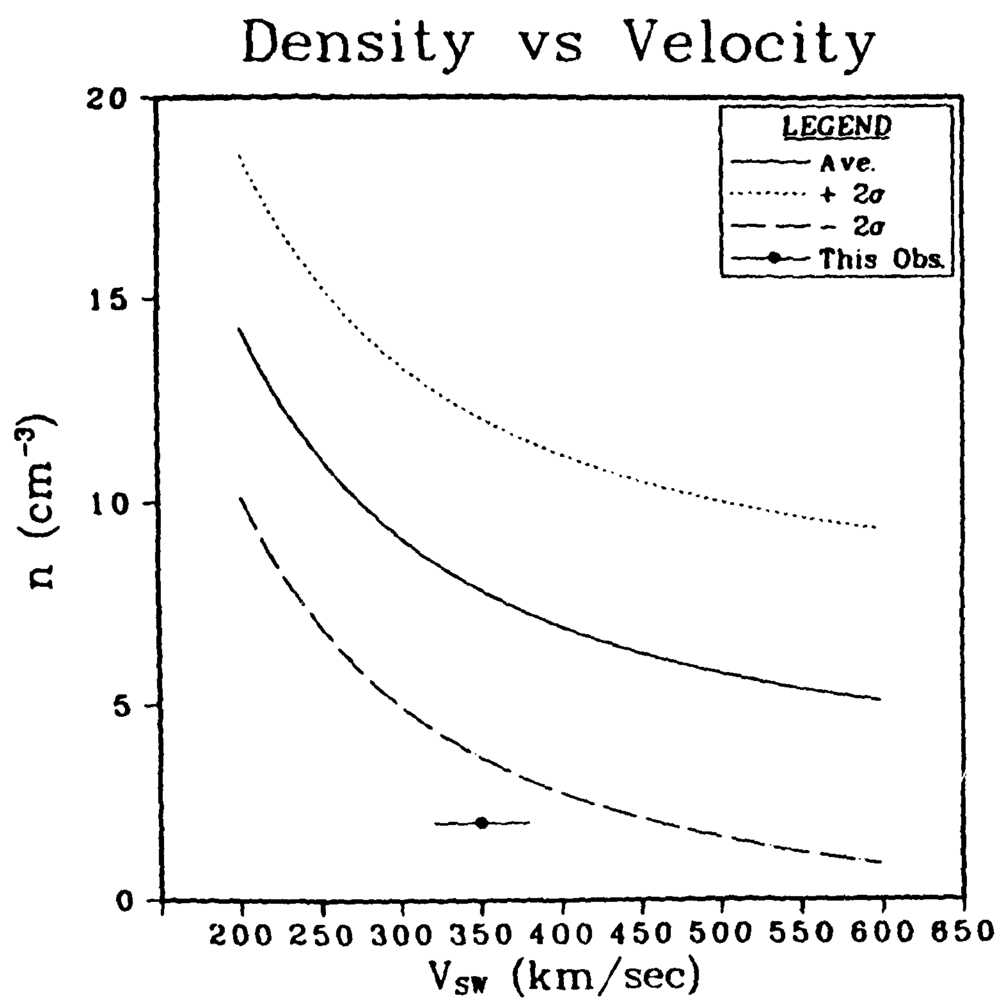

Fig. 10. Solar wind parameters for the 1100-1330 UT period on November 14, 1979. (a) The solid line is the average fit to a large number of solar wind observations of the solar wind density as a function of solar wind speed [Pizzo et al., 1973]. The $\pm$ 2σ deviations from this fit are shown. The point indicates the value observed during the 1100-1330 UT time interval.

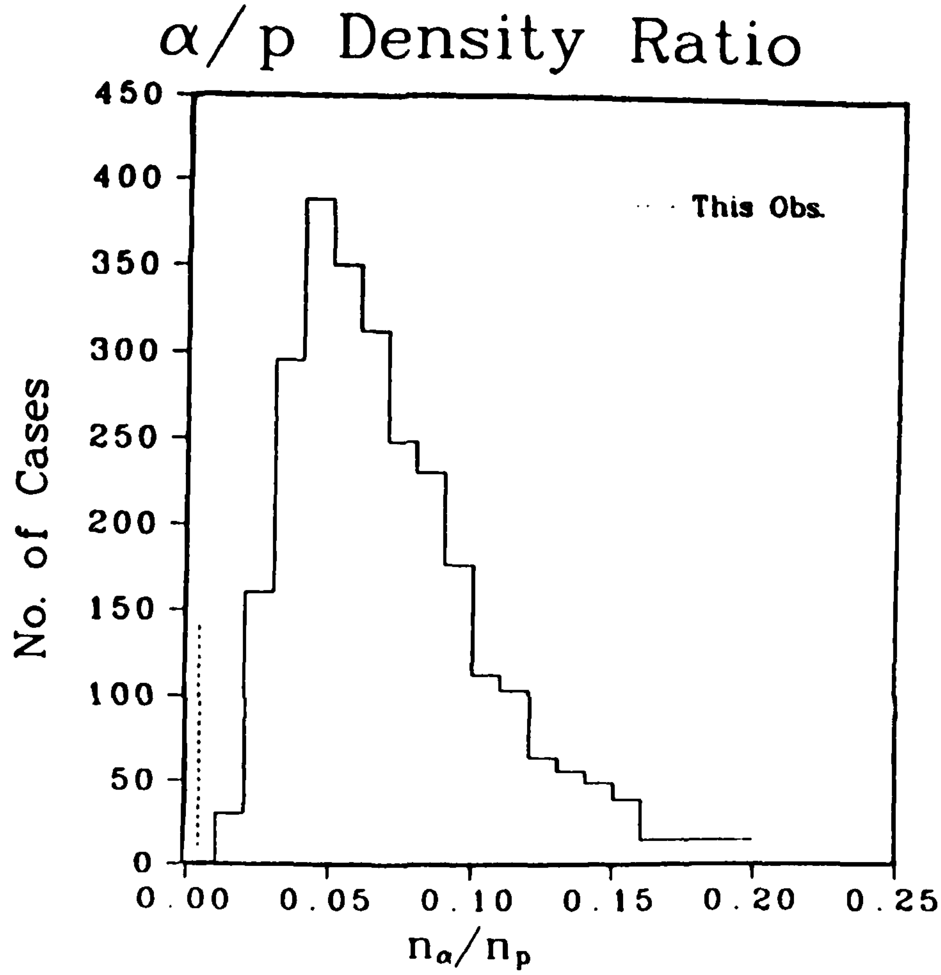

Fig. 10. Solar wind parameters for the 1100-1330 UT period on November 14, 1979. (b) The alpha-to-proton ratio during 1100-1330 UT for this event (dashed line) compared with the statistical distribution of this ratio [Ogilvie and Wilkerson, 1969].

Observation Section). The solar wind speed is such that the expected arrival time of the enhancement relative to the SC is close to that observed. P78-2 was at ~1600 LT at 0330 UT; the dayside pulsations had died away about an hour earlier as P78-2 approached the dusk portion of its orbit. When the SC arrived, pulsations with about the same period as before were observed again at P78-2 for approximately one hour. This also corresponded to the time when the ISEE-1 and -2 spacecraft finally crossed through the magnetopause, passed quickly (~5 minutes) through the magnetosheath, and emerged in the solar wind.

In Figure 11 we show a complete summary of the available data assuming that pulsations could only be observed on the dayside. In the upper part of the figure an open box was drawn vs universal time if a given spacecraft had data available and was on the dayside part of its orbit (i.e. in the 06-12-18 LT segment). Observations of pulsations outside the dayside local time segments were omitted from this figure. The box was filled if pulsations were observed during this period. The uppermost bar is a summary of all the individual spacecraft observations. Again an open box indicates data availability; solid black indicates all available spacecraft observed oscillations simultaneously; hatching indicates that at least one but not all available spacecraft observed oscillations. In the bottom half of the figure various solar wind parameters obtained by the ISEE-3 spacecraft are plotted. These parameters include the alpha-to-proton ratio, the solar wind density and bulk speed, and the solar ecliptic latitude and longitude of the IMF as well as the magnitude of B.

Discussion

It can be seen from Figure 11 that the Pc 5 oscillations appear to be present for forty-eight hours continuously with two exceptions. Early on November 14 the magnetometer records from GOES-2 and -3 show very large and

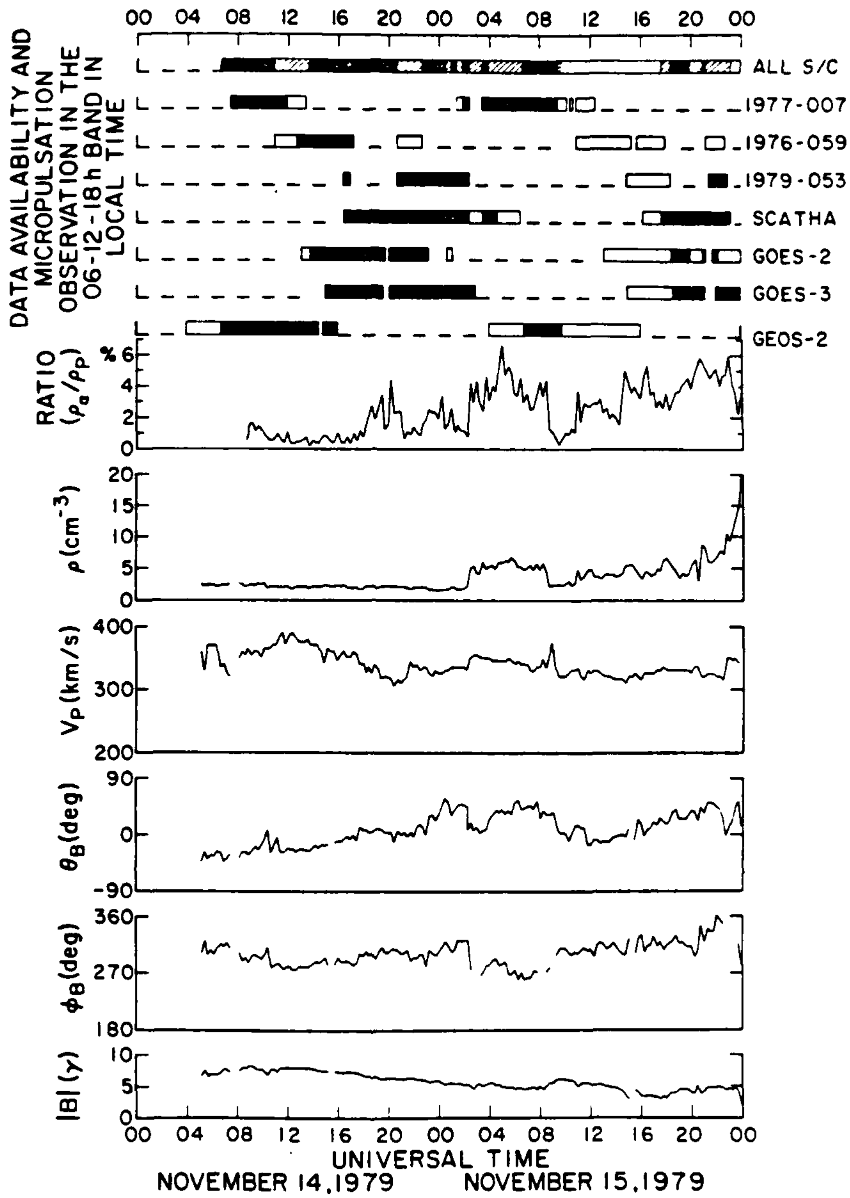

Fig. 11 See text for discussion of bar charts at top of figure. Parameters for the solar wind and IMF are plotted in the bottom part of the figure. These are: the alpha-to-proton density ratio, the solar wind density, the solar wind bulk velocity, the latitude and longitude of the interplanetary magnetic field in solar ecliptic coordinates, and the magnitude of the IMF.

erratic changes so that no period can be determined. The P78-2 magnetometer does show irregular pulsations during the intervals 2100 to 2220 and 2300 to 2400 on November 13. 1979-053 also observed irregular pulsations late on November 13. The thirteenth was very disturbed geomagnetically and this activity continuing on to the early hours of the fourteenth would tend to mask any regular pulsations.

The second period when pulsations appeared to cease were the eight hours between 0945 to 1745 UT on November 15. This appears to be a real effect since several satellites were in position to observe possible oscillations. Approximately one hour earlier a density decrease accompanied by a decrease in the alpha-to-proton ratio was observed in the solar wind by ISEE-3 and this change might be causually connected with the cessation of oscillations.

In Figure 12, data from GOES-3 and 1979-053 (positioned at 134.9°W and 134°W respectively) are compared at a time when the spacecraft were located just past local noon. A time difference of $\sim$ 3.1 minutes between the oscillation was determined (assuming the particle flux modulations should be in phase with the compressional component of the field) by overlaying the records and inspecting them visually. Analysis of the data in Figure 12 gives an azimuthal wave length of $\sim$ 290 km and an azimuthal phase velocity of $\sim$ 3.6 km/sec.

There is a vast body of work on pulsation phenomena observed by ground-based monitors of geomagnetic activity and by spacecraft instruments. The theories of these pulsations have not quite reached the point of quantative models. These theories include the following:

(1) Southwood [1968; 1973; and 1979] and Chen and Hasegawa [1974] have provided a detailed account for the origin of Pc 5 waves. In their view, waves are generated at the magnetopause boundary by the development of a Kelvin-

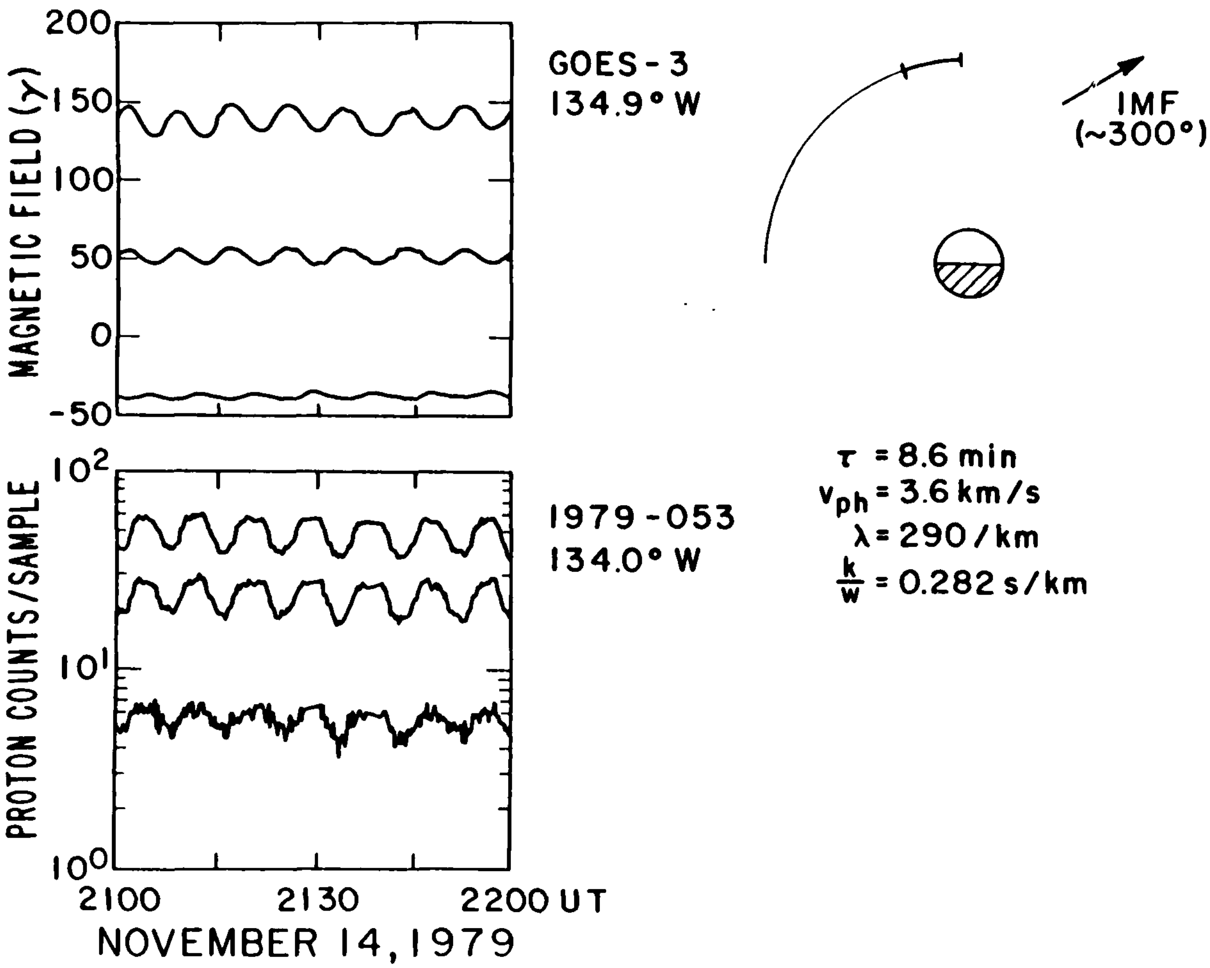

Fig. 12. Comparison of magnetic field variations with proton flux modulations. The magnetic field components are (from top to bottom) roughly, the dipole component, the radial component, and the azimuthal component. the count rate curves correspond to proton thresholds of 105, 156, and 225 keV. The insert on the upper right shows the interval in local time corresponding to the two hour interval for the data shown. The approximate interplanetary field longiutde is also indicated.

Helmholtz instability. The wave field from this source has an evanescent or exponentially decaying component in the interior of the magnetosphere. There are two subcategories of this theory [cf. Nishida, 1978]. If the surface wave at the magnetopause is monochromatic, then a field line having the same resonant frequency for oscillation can be excited by the wave field. This resonance condition corresponds to a logarithmic singularity in the simple theory, but adjacent fixed lines would likely join in a forced oscillation thus spreading out the resonant region. In the second version, the source at the magnetopause could be broad band and a stronger resonance condition - such as might be associated with the surface discontinuity presented by the plasmapause - would select out a particular frequency.

Since Kelvin-Helmholtz instabilities at the magnetopause have been invoked to explain Pc oscillations, it is useful to examine the magnetopause stability in this case. Boller and Stolov [1970] quote the following relation for the growth of a Kelvin-Helmholtz instability:

$$U^2 \geq \quad = \frac{(\rho_1 + \rho_2)}{4\pi\ \rho_1\rho_2} (B_1{}^2\cos^2\psi_1 + B_2{}^2\cos^2\psi_2) \equiv U_o^2$$

where the subscripts 1 and 2 refer to quantities on opposite sides of a boundary, ρ is the particle number density, B the magnetic field, and ψ is the angle between the magnetic field and the local flow direction. U is the relative plasma flow velocity.

The ISEE-1 and -2 spacecraft were close to each other on November 15 as they passed through the boundary layer and the magnetopause. Data from them was used to calculate the growth criterion, U_o, and to measure U. The results of these calculations are given in Table II. Apparently, for this case, the inner edge of the boundary layer is stable - contrary to the picture which was

Table II

Kelvin-Helmholtz Instability Criterion for Growth

Time of Encounter	Magnetosphere	Boundary Layer	Boundary Layer	Magnetosheath
	~0120 on November 15		~0330 on November 15	
ρ (cm^{-3})	0.3	0.8	1.3	10.0
V (km/sec)	50	160	160	200
Flow longitude	90°	230°	225°	180°
Flow latitude	60°	-15°	-20°	0°
$U = \|V_2 - V_1\|$ (km/sec)	180		94	
B_x (γ)	-5	-8	-7	5
B_y (γ)	-4	-5	-7	0
B_z (γ)	18	20	18	21

U_o = 656 km/sec (stable)

U_o = 117 km/sec (marginally stable)

derived for another event by Sckopke et al. [1980] - whereas, the magnetopause itself was close to the condition for wave growth.

(2) Another possible explanation for the Pc 5 oscillations is a collective oscillation of the entire magnetosphere. Hones et al. [1978,1980] have discussed plasma vortices which represent large scale oscillations with wavelengths characteristic of the dimensions of the entire magnetosphere (e.g. the cross tail diameter). This may be taken as a subcategory of (1) in which the frequency of a monochromatic surface wave is determined by the dispersion relation for the Kelvin-Helmholtz waves and the scale size of the magnetosphere.

(3) The fluctuating waves in the magnetosphere represent a large amount of stored energy - comparable to that released in a small substorm [Greenwald, 1980]. If some of this energy couples to the ionosphere, the ionosphere might be heated and the changing conductivity of the ionosphere may generate waves in its turn, provided an external source of energy is available such as the magnetospheric convection electric field [Lyatskaya et al., 1976].

(4) Cornwall [1976] suggested a high-β compressional drift mode instability might generate Pc 4 or Pc 5 waves.

(5) The geomagnetic field was quite disturbed on the day preceding this event. The three hour Kp averages for November 13 were 4, 5^-, 4^-, 4^+, 4, 5, 5^+, 4^+ and ΣK_p was 35^+. In fact, this day was the most disturbed day (D1) for the month. The solar wind, as measured by ISEE-3, changed from a hot plasma with a bulk velocity of $\sim$450 km/s on the thirteenth to a cooler plasma with a velocity of $\sim$350 km/s on the fourteenth. The magnetic field (cf. Figures 7 and 11) changed from an away to a toward direction; B_z was negative on the thirteenth, becoming less so on the fourteenth. It may be that the energy dumped into the magnetosphere on November 13 was simply being released slowly

when the magnetosphere was in its expanded state via some mechanism such as (3) above.

Summary

In this paper we have described a Pc 5 event which was global in character. The following features were found:

(1) The Pc 5 waves were observed primarily near geostationary orbit both as variations in the magnetic field and as modulations of the particle fluxes.

(2) The modulations were of unusually large amplitude and persisted for most of forty-eight hours. They were confined primarily to the dayside region.

(3) The geomagnetic conditions were extremely quiet and the magnetosphere was greatly expanded from its nominal size due to the abnormally low dynamic pressure from the solar wind.

(4) Control of the oscillations by parameters (such as velocity, density, magnetic field direction) in the solar wind was not obvious. Although the oscillations were associated with low dynamic pressure, a further decrease in the pressure observed by ISEE-3 (at 0830 on November 15) might have been associated with a cessation of oscillations at $\sim$ 0945.

Conclusion

One way to proceed in the study of a complex physical problem such as the dynamics of the magnetosphere is to investigate small perturbations of the quiescent system. This pulsation event may offer an opportunity to distinguish between various pulsation theories on a quantative basis. In this paper, we have shown that there is a wealth of data from satellites in the magnetosphere. This event is also observable in filtered magnetograms at ground-based stations (G. Rostoker, private communication, 1980). The event shows large effects in the data presented here, but the pattern appears to be

time stationary over intervals hours in duration. Thus, the data coverage is likely global with ground stations in many countries passing through the dayside active region and with many spacecraft taking data not reviewed here. Furthermore, since the event does seem to be time stationary, the average properties of the magnetosphere measured by various spacecraft should be valid throughout the event. For example, the plasma density recorded by ISEE-1 and -2 along their trajectory should provide a radial functional form independent of time to first approximation. Since pulsation events depend directly on the plasma properties of the magnetosphere, this event with its extensive data coverage should provide a first rate challenge to quantitative magnetospheric modelers.

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8